Addressing the "Light Precipitation Problem" in the ECMWF Global Model

Research Highlight

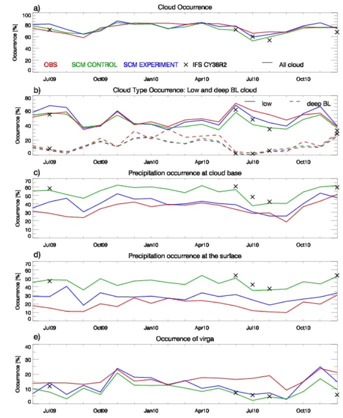
It is common for global models to overestimate the frequency of light precipitation events, but underestimate the occurrence of more rare, but intense precipitation events. Comparison with global precipitation observations suggest that the Integrated Forecast System (IFS) run at ECMWF for global numerical weather prediction (NWP) is no exception. Observations obtained during the 19 month long deployment of the AMF to Graciosa Island in the Azores provide an opportunity to further assess systematic model errors in the occurrence of clouds, liquid water path, precipitation and surface radiation. The synergy and colocation of cloud and radiation observations together with vertically resolved observations of hydrometeors (i.e. cloud and drizzle droplets) provide deeper insights into these model errors than can be gained from a satellite perspective alone.

Observations show that boundary layer clouds are the most frequently observed cloud type at Graciosa (Remillard et al., 2012), and that these are underestimated by 10% in the model. Systematic but partially compensating surface radiation errors exist and can be linked to opposing cloud cover and liquid water path errors in broken (shallow cumulus) and overcast (stratocumulus) low cloud regimes, consistent with previously reported results from the continental ARM Southern Great Plains (SGP) site. Occurrence of precipitation on the other hand is overestimated by a factor of 1.5 at cloud base and by a factor of 2 at the surface suggesting deficiencies in both the warm-rain formation and sub-cloud evaporation parameterizations.

Three specific parameterizations are identified as contributing to the model error: 1) triggering of cloud in the boundary layer and shallow convection parameterizations, 2) the autoconversion/accretion parameterization and 3) the parameterization of drizzle evaporation. The single column version of the ECMWF IFS model (SCM), forced with data from the operational model for the 19-month period, is used to assess the impact of changes to the parameterizations. A consistent representation of the test parcel entrainment is introduced in the boundary layer and shallow convection parameterizations to determine the lifting condensation level. A more non-linear autoconversion/accretion parameterization for rain based on Khairoutdinov and Kogan (2000) replaces the Sundqvist (1978) scheme. This reduces the generation of rain when cloud liquid water contents are low, but rapidly increases the conversion rate as precipitation increases. Finally, a new parameterization of rain evaporation based on Abel and Boutle (2012) is included which represents the increased numbers of small drops observed in drizzling stratocumulus, and hence enhances evaporation rates for light precipitation. Together, the three model changes in the SCM improve the occurrence of overcast low clouds, increase their liquid water path and reduce the overestimate of precipitation occurrence at cloud base and at the surface.

The SCM sensitivity results show a change in the representation of the broken cloud and overcast regimes which reduces compensating errors in the cloud radiative forcing. This is particularly evident in the shortwave radiation at the surface which is affected by cloud cover and liquid water path. A global observation dataset of top-of-atmosphere net shortwave radiation from CERES is used as a measure of the impact of the changes in an ensemble of four one-year simulations of the full global model in climate mode. The annual mean absolute error is reduced over large areas of the globe and locally by up to 10 W m-2. The changes to the parameterizations are one step towards addressing some of the long-lived cloud, precipitation and radiation related systematic errors in the ECMWF IFS model; systematic errors that have similarities in other NWP and climate models.

Abel, S. and I. Boutle, 2012: An improved representation of the raindrop size distribution for single-moment microphysics schemes. Quart. J. Roy. Meteor. Soc., 138, 2151-2162, doi:10.1002/qj.1949.



Monthly mean cloud and precipitation occurrence from observations (red), the control version of the single column model (green) and the SCM experiment (blue). (a) Total cloud occurrence. (b) Low cloud (solid) and deep boundary layer (dashed) cloud occurrence. (c) Precipitation occurrence at cloud base, (d) at the surface and (e) for virga. Symbols mark values for select months of the full IFS forecast cycle 38R2.

Khairoutdinov, M. and Y. Kogan, 2000: A new cloud physics parameterization in a large eddy simulation model of marine stratocumulus. Mon. Wea. Rev., 128 (1), 229-243.

Remillard, J., P. Kollias, E. Luke, and R. Wood, 2012: Marine boundary layer cloud observations at the Azores. J. Climate, 25 (21), 7381-7398.

Sundqvist, H., 1978: A parameterization scheme for non-convective condensation including prediction of cloud water content. Quart. J. Roy. Meteor. Soc., 104 (441), 677-690.

Reference(s)

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Cloud Life Cycle